# CRYSTAL GROWTH METHOD FOR GALLIUM NITRIDE-BASED SEMICONDUCTOR LAYER CONTAINING INGAN LAYER, GALLIUM NITRIDE-BASED LIGHT-EMITTING ELEMENT, AND MANUFACTURE THEREOF


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Abstract of **JP11054847**

PROBLEM TO BE SOLVED: To prevent the dissociation of In in an InGaN growth layer and minimize the worsening of crystallinity of a growth layer by sequentially forming the InGaN layer and an AlGaN layer at a particular substrate temperature, and by specifying the relations among the number of layers of AlGaN layers, thickness of each layer and Al composition ratio of each layer.

SOLUTION: After the growth of an InGaN growth layer and an AlGaN indium dissociation prevention layer at a substrate temperature of 600 deg.C to 900 deg.C, when the substrate is heated to temperature higher than or equal to 900 deg.C for the growth of GaN or the like, Ga atoms are evaporated from the AlGaN indium dissociation prevention layer. Because of this, the AlGaN indium dissociation prevention layer becomes an AlGaN layer with the aluminum composition being greater than that prior to raising of the temperature, and this layer prevents the slip of In atoms. Here, the relations among the number of layers, thickness of each layer di (i=1,..., N), aluminum composition xi (i=1,..., N) of each layer of an Alx Ga1-x N layer used as the indium dissociation prevention layer are so made so to satisfy the equation.

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$


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(54)【発明の名称】　ＩｎＧａＮ層を含む窒化ガリウム系半導体層の結晶成長方法および窒化ガリウム系発光素子およびその製造方法

(57)【要約】

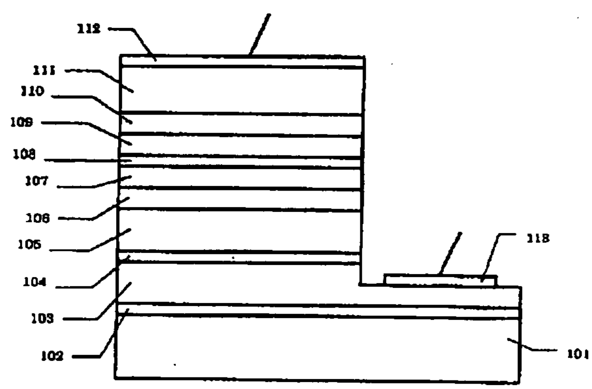
【課題】　比較的低温でＩｎＧａＮ層を形成した後に、基板の昇温に伴なってインジウムが解離することを防止し、かつ、ＩｎＧａＮ層の結晶性の悪化を最小限にとどめることの出来る、ＩｎＧａＮ層に続いて比較的低温で形成される$Al_xGa_{1-x}N$層（$0 \leq x \leq 1$）層の組成と厚さの範囲を明らかにする。

【解決手段】　基板温度６００℃以上９００℃以下で一層または複数層のＩｎＧａＮ層を形成した後に、連続して基板温度６００℃以上９００℃以下で一層または複数層の$Al_xGa_{1-x}N$層（$0 \leq x \leq 1$）層を形成し、基板温度を９００℃以上に昇温する。$Al_xGa_{1-x}N$層（$0 \leq x \leq 1$）層の層数Ｎ、各層の厚さ$d_i$（$i = 1, . . . . , N$）、各層のアルミニウム組成$x_i$（$i = 1, . . . . , N$）は、

【数１】

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

なる関係を満たすように設計する。



【特許請求の範囲】

【請求項1】InGaN 層を含む窒化ガリウム系半導体層の結晶成長方法であって、基板温度600℃以上900℃以下で$In_xGa_{1-x}N$ 層（0<x≦1）を少なくとも一層含む、一層または複数層の$In_xGa_{1-x}N$ 層（0≦x≦1）を形成する工程と、前記工程と連続して基板温度600℃以上900℃以下で$Al_xGa_{1-x}N$層（0<x≦1）を少なくとも一層含む、一層または複数層の$Al_xGa_{1-x}N$層（0≦x≦1）を形成する工程と、基板温度を900℃以上にする工程とを、前記順序で少なくとも含み、かつ、前記$Al_xGa_{1-x}N$層（0≦x≦1）の層数N、各層の厚さ$d_i$（i＝1，．．．，N）、各層のアルミニウム組成$x_i$（i＝1，．．．，N)の間に、

【数1】

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

なる関係が満たされることを特徴とする窒化ガリウム系半導体層の結晶成長方法。

【請求項2】請求項1記載の窒化ガリウム系半導体層の結晶成長方法であって、前記$Al_xGa_{1-x}N$層（0≦x≦1）が複数の層からなり、かつ、前記複数層の$Al_xGa_{1-x}N$層（0≦x≦1）のアルミニウム組成が基板側から表面側にかけて増加することを特徴とする窒化ガリウム系半導体層の結晶成長方法。

【請求項3】InGaN層を含む窒化ガリウム系発光素子の製造方法であって、基板温度600℃以上900℃以下で$In_xGa_{1-x}N$層（0<x≦1）を少なくとも一層含む、一層または複数層の$In_xGa_{1-x}N$層（0≦x≦1）を形成する工程と、前記工程と連続して基板温度600℃以上900℃以下で$Al_xGa_{1-x}N$層（0<x≦1）を少なくとも一層含む、一層または複数層の$Al_xGa_{1-x}N$層（0≦x≦1）を形成する工程と、基板温度を900℃以上にする工程とを、前記順序で少なくとも含み、かつ、前記$Al_xGa_{1-x}N$層（0≦x≦1）の層数N、各層の厚さ$d_i$（i＝1，．．．，N）、各層のアルミニウム組成$x_i$（i＝1，．．．，N)の間に、

【数2】

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

なる関係が満たされることを特徴とする窒化ガリウム系発光素子の製造方法。

【請求項4】請求項3記載の窒化ガリウム系発光素子の製造方法であって、前記$Al_xGa_{1-x}N$層（0≦x≦1）が複数の層からなり、かつ、前記複数層の$Al_xGa_{1-x}N$層（0≦x≦1）のアルミニウム組成が基板側から表面側にかけて増加することを特徴とする窒化ガリウム系発光素子の製造方法。

【請求項5】請求項3または4記載の窒化ガリウム系発光素子の製造方法であって、前記$In_xGa_{1-x}N$層（0≦x≦1）は活性層または発光層であることを特徴とする窒化ガリウム系発光素子の製造方法。

【請求項6】基板上と、前記基板上に基板温度600℃以上900℃以下で成長した$In_xGa_{1-x}N$層（0<x≦1）を少なくとも一層含む、一層または複数層の$In_xGa_{1-x}N$層（0≦x≦1）と、前記$In_xGa_{1-x}N$層（0≦x≦1）に続いて基板温度600℃以上900℃以下で$Al_xGa_{1-x}N$層（0<x≦1)を少なくとも一層含む、一層または複数層の$Al_xGa_{1-x}N$層（0≦x≦1)を成長した後に基板温度を900℃以上にして形成した$Al_xGa_{1-x}N$層（0<x≦1)とを有し、前記$Al_xGa_{1-x}N$層（0≦x≦1)の層数N、各層の厚さ$d_i$（i＝1，．．．，N)、各層のアルミニウム組成$x_i$（i＝1，．．．，N)の間に、

【数3】

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

なる関係が満たされることを特徴とする窒化ガリウム系発光素子。

【請求項7】請求項6記載の窒化ガリウム系発光素子であって、前記$Al_xGa_{1-x}N$層（0≦x≦1)が複数の層からなり、かつ、前記複数層の$Al_xGa_{1-x}N$層（0≦x≦1)のアルミニウム組成が基板側から表面側にかけて増加することを特徴とする窒化ガリウム系発光素子。

【請求項8】請求項6または7記載の窒化ガリウム系発光素子であって、前記$In_xGa_{1-x}N$層（0≦x≦1)活性層または発光層であることを特徴とする窒化ガリウム系発光素子。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、一般式$In_xGa_{1-x}N$（0<x≦1）で表される半導体層を少なくとも1層含む、一層あるいは複数層の$In_xGa_{1-x}N$（0≦x≦1）を有する窒化ガリウム系半導体層の結晶成長方法に関する。

【0002】また一般式$In_xGa_{1-x}N$（0<x≦1）で表される半導体層を少なくとも1層含む、一層あるいは複数層の$In_xGa_{1-x}N$（0≦x≦1）を有する窒化ガリウム系発光素子及びその製造方法に関する。

【0003】

【従来の技術】窒化ガリウムは、燐化インジウムや砒化ガリウムといった他の一般的な化合物半導体に比べ、禁制帯エネルギーが大きい。そのため、一般式$In_xAl_yGa_{1-x-y}N$（0≦x≦1、0≦y≦1、0≦x+y≦1）で表される半導体（以下窒化ガリウム系半導体）

は緑から紫外にかけての発光素子、特に半導体レーザ（以下単にレーザ）への応用が期待されている。

【０００４】従来、窒化ガリウムの結晶成長には９００℃程度以上の基板温度が必要であるにも関らず、一般式 $In_x Ga_{1-x} N$（０≦ｘ≦１）で表される半導体層の結晶成長は、インジウムの蒸気圧が高いために、比較的低温である６００℃ないし９００℃程度の基板温度で行われていた。

【０００５】《従来例１》図１０は、従来のＩｎＧａＮ層の結晶成長方法により、多重量子井戸構造の活性層が形成された、窒化ガリウム系レーザの概略断面図である（S. Nakamuraet Ａｌ., Extended Abstracts of 1996 International Conferenceon Solid State Devices and Materials, yokohama,1996, pp. 67-69）。図１０に於いて、この窒化ガリウム系レーザは、（１１－２０）面を表面とするサファイア基板１０１上に、厚さ３００Ａ（オングストローム）のアンドープの窒化ガリウム低温成長バッファ層１０２、珪素が添加された厚さ３μm のN型窒化ガリウムコンタクト層１０３、珪素が添加された厚さ０．１μm のN型 $In_{0.05} Ga_{0.95}N$ クラック防止層１０４、珪素が添加された厚さ０．４μmのN型 $Al_{0.07}Ga_{0.93}N$ クラッド層１０５、珪素が添加された厚さ０．１μm のN型窒化ガリウム光ガイド層１０６、厚さ２５Ａ（オングストローム）のアンドープの $In_{0.2} Ga_{0.8} N$ 量子井戸層と厚さ５０Ａ（オングストローム）のアンドープの $In_{0.05} Ga_{0.95} N$ 障壁層からなる７周期の多重量子井戸構造活性層１０７、マグネシウムが添加された厚さ２００Ａ（オングストローム）のｐ型 $Al_{0.2} Ga_{0.8} N$ 層６０８、マグネシウムが添加された厚さ０．１μm のｐ型窒化ガリウム光ガイド層１０９、マグネシウムが添加された厚さ０．４μmのｐ型 $Al_{0.07}Ga_{0.93}N$ クラッド層１１０、マグネシウムが添加された厚さ０．２μm のｐ型窒化ガリウムコンタクト層１１１、ニッケル（第１層）および金（第２層）からなるｐ電極１１２、チタン（第１層）およびアルミニウム（第２層）からなるN電極１１３が形成されている。多重量子井戸構造活性層１０７およびｐ型 $Al_{0.2} Ga_{0.8} N$ 層６０８は基板温度８００℃で、ｐ型窒化ガリウム光ガイド層１０９、ｐ型 $Al_{0.07}Ga_{0.93}N$ クラッド層１１０、ｐ型窒化ガリウムコンタクト層１１１は基板温度１０２０℃で形成された。

【０００６】《従来例２》図１１は、従来のＩｎＧａＮ層の結晶成長方法により、発光層が形成された、従来の窒化ガリウム系発光ダイオードの概略断面図である（S. Nakamura et Al.,Jpn.J.Appl.phys.32(1993)L8）。図１１に於いて、この窒化ガリウム系発光ダイオードは、（０００１）面を表面とするサファイア基板２０１上に、厚さ２５０Ａ（オングストローム）のアンドープの窒化ガリウム低温成長バッファ層１０２、珪素が添加された厚さ４μm のN型窒化ガリウムコンタクト層１０３、珪素が添加された厚さ２００Ａ（オングストローム）の $In_{0.2} Ga_{0.8} N$ 発光層２０７、マグネシウムが添加されたｐ型窒化ガリウムコンタクト層１１１、金からなるｐ電極２１２、アルミニウムからなるN電極２１３が形成されている。$In_{0.2} Ga_{0.8} N$ 発光層２０７およびアンドープの $Al_{0.2} Ga_{0.8} N$ 層６０８は基板温度８００℃で、ｐ型窒化ガリウムコンタクト層１１１は基板温度１０２０℃で形成された。

【０００７】

【発明が解決しようとする課題】図１０に示された、従来のＩｎＧａＮ層の結晶成長方法により活性層が形成された窒化ガリウム系レーザに於いては、基板温度８００℃での多重量子井戸構造活性層１０７の形成が終了した後、ｐ型窒化ガリウム光ガイド層１０９を形成するために基板を１０２０℃まで昇温する際に、多重量子井戸構造活性層１０７中のインジウムが解離することを防止するために、多重量子井戸構造活性層１０７よりも表面側に、多重量子井戸構造活性層１０７に接して、多重量子井戸構造活性層１０７と同じ基板温度８００℃で、$Al_{0.2} Ga_{0.8} N$ 層６０８が形成されている。しかし、$In_x Ga_{1-x} N$（０≦ｘ≦１）と $Al_x Ga_{1-x} N$（０＜ｘ≦１）は格子定数が異なるにも関らず、従来例１では $Al_{0.2} Ga_{0.8} N$ 層６０８の厚さが２００Ａ（オングストローム）と厚く、かつ、アルミニウム組成も０．２と大きいために、大きな格子歪が多重量子井戸構造活性層１０７に加わり、多重量子井戸構造活性層１０７の結晶性の悪化がもたらされている。一方、ｐ型 $Al_{0.2} Ga_{0.8} N$ 層６０８の厚さを薄く、または、アルミニウム組成を小さくした場合、基板の昇温により多重量子井戸構造活性層１０７中のインジウムが解離することを防止でない恐れがある。

【０００８】図１１に示された、従来のＩｎＧａＮ層の結晶成長方法により発光層が形成された窒化ガリウム系発光ダイオードに於いては、基板温度８００℃での $In_{0.2}Ga_{0.8}$ N発光層２０７の形成が終了した後、ｐ型窒化ガリウムコンタクト層１１１を形成するために基板を１０２０℃まで昇温する際に、$In_{0.2} Ga_{0.8} N$ 発光層２０７中のインジウムが解離し、設計値通りの発光波長で発光しない怖れがある。

【０００９】本発明の目的は、$In_x Ga_{1-x} N$ 層（０＜ｘ≦１）を少なくとも一層含む、一層または複数層の比較的低温で形成された $In_x Ga_{1-x} N$ 成長層（０≦ｘ≦１）を有する窒化ガリウム系半導体層の中のインジウムが、基板温度を９００℃以上とすることに伴なって解離するのを防止し、かつ、$In_x Ga_{1-x} N$ 成長層（０≦ｘ≦１）の結晶性の悪化を最小限にとどめることのできる、$In_x Ga_{1-x} N$ 成長層（０≦ｘ≦１）よりも表面側に、$In_x Ga_{1-x} N$ 成長層（０≦ｘ≦１）に接して、$Al_x Ga_{1-x} N$ 層（０＜ｘ≦１）を少なくと

も一層含む、一層または複数層の比較的低温で形成される$Al_xGa_{1-x}N$インジウム解離防止層（$0 \leqq x \leqq 1$）の組成と厚さの範囲を明らかにすることによって、結晶性の良い$In_xGa_{1-x}N$成長層（$0 \leqq x \leqq 1$）を形成できる結晶成長方法を提供することである。

【0010】さらに、このような結晶成長方法を用いて、しきい値電流などの特性の良い窒化ガリウム系発光素子を提供することである。

【0011】

【課題を解決するための手段】本発明の窒化ガリウム系半導体の結晶成長方法は、基板温度６００℃以上９００℃以下で$In_xGa_{1-x}N$層（$0 < x \leqq 1$）を少なくとも一層含む、一層または複数層の$In_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）を形成する工程と、前記工程と連続して基板温度６００℃以上９００℃以下で$Al_xGa_{1-x}N$層（$0 < x \leqq 1$）を少なくとも一層含む、一層または複数層の$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）を形成する工程と、基板温度を９００℃以上にする工程とを、前記順序で少なくとも含み、かつ、前記$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）の層数N、各層の厚さ$d_i$（$i = 1, \ldots, N$）、各層のアルミニウム組成$x_i$（$i = 1, \ldots, N$）の間に、

【0012】

【数4】

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

【0013】なる関係が満たされることを特徴とする。

【0014】また、前記$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）が複数の層からなり、かつ、前記複数層の$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）のアルミニウム組成が基板側から表面側にかけて増加することを特徴とする。

【0015】本発明の窒化ガリウム系発光素子の製造方法は、基板温度６００℃以上９００℃以下で$In_xGa_{1-x}N$層（$0 < x \leqq 1$）を少なくとも一層含む、一層または複数層の$In_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）を形成する工程と、前記工程と連続して基板温度６００℃以上９００℃以下で$Al_xGa_{1-x}N$層（$0 < x \leqq 1$）を少なくとも一層含む、一層または複数層の$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）を形成する工程と、基板温度を９００℃以上にする工程とを、前記順序で少なくとも含み、かつ、前記$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）の層数N、各層の厚さdi（i＝１，．．．．，N）、各層のアルミニウム組成xi（i＝１，．．．．，N）の間に、

【0016】

【数5】

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

【0017】なる関係が満たされることを特徴とする。

【0018】また前記$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）が複数の層からなり、かつ、前記複数層の$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）のアルミニウム組成が基板側から表面側にかけて増加することを特徴とする。

【0019】本発明の窒化ガリウム系発光素子は、基板上と、前記基板上に基板温度６００℃以上９００℃以下で成長した$In_xGa_{1-x}N$層（$0 < x \leqq 1$）を少なくとも一層含む、一層または複数層の$In_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）と、前記$In_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）に続いて基板温度６００℃以上９００℃以下で$Al_xGa_{1-x}N$層（$0 < x \leqq 1$）を少なくとも一層含む、一層または複数層の$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）を成長した後に基板温度を９００℃以上にして形成した$Al_xGa_{1-x}N$層（$0 < x \leqq 1$）とを有し、前記$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）の層数N、各層の厚さ$d_i$（$i = 1, \ldots, N$）、各層のアルミニウム組成$x_i$（$i = 1, \ldots, N$）の間に、

【0020】

【数6】

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

【0021】なる関係が満たされることを特徴とする。

【0022】また前記$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）が複数の層からなり、かつ、前記複数層の$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）のアルミニウム組成が基板側から表面側にかけて増加することを特徴とする。

【0023】

【発明の実施の形態】本発明の実施の形態について、図面を参照して詳しく説明する。本実施の形態では、基板上に比較的低温で形成された$In_xGa_{1-x}N$層（$0 < x \leqq 1$）を少なくとも一層含む、一層または複数層の$In_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）（以下、$In_xGa_{1-x}N$成長層（$0 \leqq x \leqq 1$）と記す）中のインジウムが、基板の昇温に伴なって解離することを防止するために、$In_xGa_{1-x}N$成長層（$0 \leqq x \leqq 1$）よりも表面側に、$In_xGa_{1-x}N$成長層（$0 \leqq x \leqq 1$）に接して、比較的低温で形成される$Al_xGa_{1-x}N$層（$0 < x \leqq 1$）を少なくとも一層含む、一層または複数層の$Al_xGa_{1-x}N$層（$0 \leqq x \leqq 1$）（以下、$Al_xGa_{1-x}N$インジウム解離防止層（$0 \leqq x \leqq 1$）と記す）を形成している。

【0024】通常GaNの成長は１０００℃程度以上の基板温度で行うが、これはN原子のみならず、Ga原子もまた蒸発する温度である。しかし、Al原子の蒸発にはさらに高温（１２００℃程度以上）が必要となる。したがって基板温度６００℃以上９００℃以下で$In_xGa_{1-x}N$成長層（$0 \leqq x \leqq 1$）、$Al_xGa_{1-x}N$インジウム解離防止層（$0 \leqq x \leqq 1$）を成長した後に、GaN等の成長のために基板を９００℃以上にした場合、G

a原子が$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1）から蒸発する。このため、$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1）は昇温前よりAl組成が大きくなった$Al_x Ga_{1-x}$ N層（0＜x≦1）となり、この層がIn原子の抜けを防止する。なおGaの蒸発の割合は、$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1）を形成した際の温度、昇温後の温度、昇温の速さ、昇温してから成長を始めるまでの待機時間などに依存して変化する。

【0025】ここで昇温時に作成されたAl組成が大きくなった$Al_x Ga_{1-x}$ N層（0＜x≦1）は、格子定数が$In_x Ga_{1-x}$ N成長層（0≦x≦1）と異なるため、$In_x Ga_{1-x}$ N成長層（0≦x≦1）の結晶性に悪化を与えることになる。

【0026】この結晶性の悪化の影響を最小限にとどめるために、Ga原子の蒸発によってAl組成の大きくなった$Al_x Ga_{1-x}$ N層（0＜x≦1）のパラメータとして$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1）におけるAl組成と層厚の積に着目した。$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1）のAl組成と層厚が$In_x Ga_{1-x}$ N成長層（0≦x≦1）層に与える影響を調べるため、$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1））の組成と厚さをAl組成0．1、厚さが25A（オングストローム）の$Al_{0.1} Ga_{0.9}$ N層（試料1）、Al組成0．1、厚さが50A（オングストローム）の$Al_{0.1} Ga_{0.9}$ N層（試料2）、Al組成0．1、厚さが100A（オングストローム）の$Al_{0.1} Ga_{0.9}$ N層（試料3）とする3種類の試料を作成した。

【0027】以下、$In_x Ga_{1-x}$ N成長層（0≦x≦1）層に接して形成する$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1）の組成と厚さの最適な範囲について説明する。

【0028】図5は、作成した3種類の試料に共通な概略断面図である。図5に於いて、試料は、有機金属化学気相成長法により、厚さ330μm の（11－20）面を表面とするサファイア基板上101に、窒化ガリウム低温バッファ層102、アンドープの厚さ1μm の窒化ガリウム層501、基板温度650℃でアンドープの厚さ30A（オングストローム）の$In_{0.2} Ga_{0.8}$ N量子井戸層とアンドープの厚さ90A（オングストローム）の窒化ガリウム障壁層とからなる5周期の多重量子井戸構造502、アンドープのAl0．1Ga0．9Nインジウム解離防止層503を形成し、基板温度1050℃に昇温した後、アンドープの厚さ0．1μm の窒化ガリウム層504を形成した。

【0029】図6は、図5に示された$Al_{0.1} Ga_{0.9}$ N層503の厚さが25A（オングストローム）の試料1、図7は$Al_{0.1} Ga_{0.9}$ N層503の厚さが50A（オングストローム）の試料2、図8は、$Al_{0.1} Ga_{0.9}$ N層503の厚さが100A（オングストローム）の試料3の室温に於けるpLスペクトルの測定結果である。pLスペクトルの測定に於ける励起光源としては、波長325Nm のHe－Cdレーザを用いた。

【0030】従来例の$Al_{0.2} Ga_{0.8}$ N層608は厚さ200A（オングストローム）、アルミニウム組成0．2であるが、$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1）の厚さとアルミニウム組成の積を従来例の$Al_{0.2} Ga_{0.8}$ N層608より小さくしても、インジウムの解離を防止するという目的に支障がない場合は、厚さとアルミニウム組成の積を小さくした方が不要な格子歪がInGaN層に導入されないため望ましい。

【0031】しかし、組成と厚さの積が2A（オングストローム）程度以下になると、基板昇温時にGa原子が$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1）から全て蒸発した場合に、単原子層未満の窒化アルミニウム（AlN）しか残らないため、インジウムの解離を防止するという目的に支障がある。したがって成長する$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1）のAl組成と厚さの積の下限は2A（オングストローム）より大きいことが望ましい。

【0032】一方、試料1～3に於いて、図6に示されたpLスペクトルの半値全幅は105meV 、図7に示されたpLスペクトルの半値全幅は85meV 、図8に示されたpLスペクトルの半値全幅は120meV であって、図7に比べ図6および図5に示されたpLスペクトルの半値全幅が広くなる。

【0033】試料1～3のpLスペクトルの測定結果から得られた、$AL_{0.1} Ga_{0.9}$ Nインジウム解離防止層の厚さとpLスペクトルの半値全幅の関係を示すグラフを図9に示す。窒化ガリウム系レーザのしきい値電流密度と、その活性層の室温に於けるpLスペクトルの半値全幅は密接な関係があり、しきい値電流密度を2kA/cm$^2$程度以下を実現するためには、その活性層の室温に於けるpLスペクトルの半値全幅が120meV 程度以下であることが望ましい。$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1）のAl組成と層厚の積が大きくなると、不要な歪が$In_x Ga_{1-x}$ N成長層（0≦x≦1）に加わりpLスペクトルの半値全幅に影響を与えることになる。したがって、$Al_x Ga_{1-x}$ Nインジウム解離防止層（0≦x≦1）の厚さとアルミニウム組成の積の上限は10A（オングストローム）より小さいことが望ましい。

【0034】このようにインジウム解離防止層として用いる$Al_x Ga_{1-x}$ N層（0≦x≦1）の層数N、各層の厚さ$d_i$ （i＝1，．．．，N）、各層のアルミニウム組成$x_i$ （i＝1，．．．，N）の関係が、次の（1）式

【0035】

【数7】

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

【0036】を満たす範囲であればよいことがわかる。

【0037】なお、図9において、Ａｌ組成０．１の場合の層厚として６０Ａ（オングストローム）付近でｐＬスペクトル半値全幅（meV　）が最も小さくなるのはインジウムの蒸発防止と不要な歪の低減という２つのトレードオフからもたらされるものである。

【0038】以下に、本発明の実施の形態を適用した実施例を説明する。

【0039】《実施例１》図１は、実施の形態で説明したインジウム解離防止層の組成と層厚の関係を適用して形成された、本発明の窒化ガリウム系レーザの概略断面図である。図１に於いて、この窒化ガリウム系レーザは、（１１－２０）面を表面とするサファイア基板１０１上に、厚さ３００Ａ（オングストローム）のアンドープの窒化ガリウム低温成長バッファ層１０２、珪素が添加された厚さ３μm　のＮ型窒化ガリウムコンタクト層１０３、珪素が添加された厚さ０．１μm　のＮ型$In_{0.05}Ga_{0.95}N$クラック防止層１０４、珪素が添加された厚さ０．４μm　のＮ型$Al_{0.07}Ga_{0.93}N$クラッド層１０５、珪素が添加された厚さ０．１μm　のＮ型窒化ガリウム光ガイド層１０６が形成され、基板温度８００℃で厚さ２５Ａ（オングストローム）のアンドープの$In_{0.2}Ga_{0.8}N$量子井戸層と厚さ５０Ａ（オングストローム）のアンドープの$In_{0.05}Ga_{0.95}N$障壁層からなる７周期の多重量子井戸構造活性層１０７、マグネシウムが添加された厚さ５０Ａ（オングストローム）のｐ型$Al_{0.1}Ga_{0.9}N$層１０８が形成され、その後基板温度１０２０℃でマグネシウムが添加された厚さ０．１μm　のｐ型窒化ガリウム光ガイド層１０９、マグネシウムが添加された厚さ０．４μm　のｐ型$Al_{0.07}Ga_{0.93}N$クラッド層１１０、マグネシウムが添加された厚さ０．２μm　のｐ型窒化ガリウムコンタクト層１１１が形成されている。ｐ電極１１２には、ニッケル（第１層）および金（第２層）を用い、Ｎ電極１１３には、チタン（第１層）およびアルミニウム（第２層）を用いている。

【0040】実施例１に於いては、$Al_{0.1}Ga_{0.9}N$層１０８の厚さとして５０Ａ（オングストローム）を、アルミニウム組成として０．１を採用することにより、$Al_{0.1}Ga_{0.9}N$層１０８により多重量子井戸構造活性層１０７中のインジウムの解離を防止することと、$Al_{0.1}Ga_{0.9}N$層１０８による多重量子井戸構造活性層１０７の結晶性の悪化を最小限にとどめることを両立させた。そのため、従来例１に示された従来のＩｎＧａＮ層の結晶成長方法により活性層が形成された窒化ガリウム系レーザに比べ、低い発振しきい値電流が実現される。

【0041】《実施例２》図２は、本発明のＩｎＧａＮ層の結晶成長方法を用いて発光層が形成された、本発明の窒化ガリウム系発光ダイオードの概略断面図である。図２に於いて、この窒化ガリウム系発光ダイオードは、（０００１）面を表面とするサファイア基板２０１上に、厚さ２５０Ａ（オングストローム）のアンドープの窒化ガリウム低温成長バッファ層１０２、珪素が添加された厚さ４μm　のＮ型窒化ガリウムコンタクト層１０３が形成され、基板温度８００℃で珪素が添加された厚さ２００Ａ（オングストローム）の$In_{0.2}Ga_{0.8}N$発光層２０７、厚さ２５Ａ（オングストローム）のアンドープの$Al_{0.2}Ga_{0.8}N$層２０８が形成され、基板温度１０２０℃でマグネシウムが添加されたｐ型窒化ガリウムコンタクト層１１１が形成されている。ｐ電極２１２には金、Ｎ電極２１３にはアルミニウムが用いられている。

【0042】実施例２に於いては、$Al_{0.2}Ga_{0.8}N$層２０８の厚さとして２５Ａ（オングストローム）を、アルミニウム組成として０．２を採用することにより、$Al_{0.2}Ga_{0.8}N$層２０８により$In_{0.2}Ga_{0.8}N$発光層２０７中のインジウムの解離を防止することと、$Al_{0.2}Ga_{0.8}N$層２０８による$In_{0.2}Ga_{0.8}N$発光層２０７の結晶性の悪化を最小限にとどめることを両立させたため、従来例２に示された従来のＩｎＧａＮ層の結晶成長方法により発光層が形成された窒化ガリウム系発光ダイオードに比べ、設計値通りの発光波長および狭い半値全幅の発光スペクトルが実現される。

【0043】《実施例３》図３は、本発明のＩｎＧａＮ層の結晶成長方法を用いて活性層が形成された、本発明の窒化ガリウム系レーザの概略断面図である。図３に於いて、この窒化ガリウム系レーザは、（１１－２０）面を表面とするサファイア基板１０１上に、厚さ３００Ａ（オングストローム）のアンドープの窒化ガリウム低温成長バッファ層１０２、珪素が添加された厚さ３μm　のＮ型窒化ガリウムコンタクト層１０３、珪素が添加された厚さ０．１μm　のＮ型$In_{0.05}Ga_{0.95}N$クラック防止層１０４、珪素が添加された厚さ０．４μm　のＮ型$Al_{0.07}Ga_{0.93}N$クラッド層１０５、珪素が添加された厚さ０．１μm　のＮ型窒化ガリウム光ガイド層１０６が形成され、基板温度８００℃で、厚さ２５Ａ（オングストローム）のアンドープの$In_{0.2}Ga_{0.8}N$量子井戸層と厚さ５０Ａ（オングストローム）のアンドープの$In_{0.05}Ga_{0.95}N$障壁層からなる７周期の多重量子井戸構造活性層１０７が形成され、その後、基板温度１０２０℃でマグネシウムが添加された厚さ５０Ａ（オングストローム）のｐ型ＡｌＧａＮ層３０８、マグネシウムが添加された厚さ０．１μm　のｐ型窒化ガリウム光ガイド層１０９、マグネシウムが添加された厚さ０．４μm　のｐ型$Al_{0.07}Ga_{0.93}N$クラッド層１１０、マグネシウムが添加された厚さ０．２μm　のｐ型

窒化ガリウムコンタクト層111が形成される。p電極112には、ニッケル（第1層）および金（第2層）を、N電極113には、チタン（第1層）およびアルミニウム（第2層）が用いられている。

【0044】p型AlGaN層308はそれぞれ異なるアルミニウム組成の複数の層からなっている。p型AlGaN層308の詳細を示す概略断面図を図4に示す。図4に於いて、 p型AlGaN層308は、マグネシウムが添加された厚さ10A（オングストローム）のp型$Al_{0.05}Ga_{0.95}N$層401、マグネシウムが添加された厚さ10A（オングストローム）のp型$Al_{0.075}Ga_{0.925}N$層402、マグネシウムが添加された厚さ10A（オングストローム）のp型$Al_{0.1}Ga_{0.9}N$層403、マグネシウムが添加された厚さ10A（オングストローム）のp型$Al_{0.125}Ga_{0.875}N$層404、マグネシウムが添加された厚さ10A（オングストローム）のp型$Al_{0.15}Ga_{0.85}N$層405からなる。

【0045】実施例3に於いては、AlGaN層308を、アルミニウム組成が基板側から表面側にかけて増加する、それぞれ厚さ10A（オングストローム）の5層により構成することにより、前記AlGaN層308により多重量子井戸構造活性層107中のインジウムの解離を防止することと、前記AlGaN層308による多重量子井戸構造活性層107の結晶性の悪化を最小限にとどめることを両立させた。そのため、実施例1に示された本発明のInGaN層の結晶成長方法により活性層が形成された窒化ガリウム系レーザに比べても、さらに低い発振しきい値電流が実現される。

【0046】上記実施例1および実施例3に記載の窒化ガリウム系レーザ及び実施例2に記載の窒化ガリウム系発光ダイオードは、（11－20）面を表面とするサファイア基板上に形成されているが、（0001）面を表面とするサファイア基板上に形成しても、本発明の実施に支障はない。

【0047】さらに、上記実施例1～3に記載の窒化ガリウム系発光素子は、（0001）面または（11－20）面を表面とするサファイア基板上に形成しなくとも、例えば炭化珪素基板あるいは$MgAl_2O_4$基板あるいは窒化ガリウム基板あるいは（0001）面および（11－20）面以外の面を表面とするサファイア基板といった他の基板上に形成した場合も、本発明の実施に支障はない。

【0048】また、本発明の実施は上記実施例に示された構造の窒化ガリウム系発光素子に限られるものではなく、各層の層厚や各層の組成や各層のドーピング濃度や電極材料などの様々な組み合わせの窒化ガリウム系発光素子に於いて支障はない。

【0049】また、インジウムの解離を防止する$Al_xGa_{1-x}N$層（0≦x≦1）は、上記実施例1および実施例3に示されたようなマグネシウムが添加されたp型、あるいは上記実施例2に示されたようなアンドープである必要はなく、珪素などが添加されたN型であっても、本発明の実施に支障はない。

【0050】また、インジウムの解離を防止する$Al_xGa_{1-x}N$層（0≦x≦1）は、アルミニウム組成の異なる複数の層からなっていても、たとえそれが上記実施例3に示されたようなアルミニウム組成が基板側から表面側にかけて増加するものでなくとも、実施例1に示された窒化ガリウム系レーザの単層の$Al_xGa_{1-x}N$層（0≦x≦1）と同等の効果はある。また実施例2にも適用可能である。

【0051】また$Al_{0.1}Ga_{0.9}N$ on GaN on $Al_{0.2}Ga_{0.8}N$ on GaNのような多層膜のインジウム解離層では各Al組成と膜厚を考慮し、かつ、600℃以上900℃以下の比較的低温で多層膜を成長しておけばよい。

【0052】なお、本実施例では、$In_xGa_{1-x}N$成長層（0≦x≦1）を活性層または発光層とした場合について記載したが、これに限られるものではない。

【0053】

【発明の効果】本発明は、$In_xGa_{1-x}N$層（0＜x≦1）を少なくとも一層含む、一層または複数層の$In_xGa_{1-x}N$成長層（0≦x≦1）を有する窒化ガリウム系半導体層において、基板温度が900℃以上になっても、インジウムの解離を防止することができ、かつ、$In_xGa_{1-x}N$成長層（0≦x≦1）の結晶性の悪化を最小限にとどめることができる。

【0054】また結晶性の良い$In_xGa_{1-x}N$成長層（0≦x≦1）を形成できるため、しきい値電流などの特性の良い発光素子を提供するができる。

【図面の簡単な説明】

【図1】実施例1に示された、本発明のInGaN層の結晶成長方法を用いて活性層が形成された、本発明の窒化ガリウム系レーザの概略断面図である。

【図2】実施例2に示された、本発明のInGaN層の結晶成長方法を用いて発光層が形成された、本発明の窒化ガリウム系発光ダイオードの概略断面図である。

【図3】実施例3に示された、本発明のInGaN層の結晶成長方法を用いて活性層が形成された、本発明の窒化ガリウム系レーザの概略断面図である。

【図4】図7に示された本発明の窒化ガリウム系レーザのAlGaNインジウム解離防止層の概略断面図である。

【図5】試料1～3の概略断面図である。

【図6】試料1のpLスペクトルの測定結果を示すグラフである。

【図7】試料2のpLスペクトルの測定結果を示すグラフである。

【図8】試料3のpLスペクトルの測定結果を示すグラフである。

【図9】試料1～3に於ける、$Al_{0.1}Ga_{0.9}N$インジウム解離防止層の厚さとｐＬスペクトルの半値全幅の関係を示すグラフである。

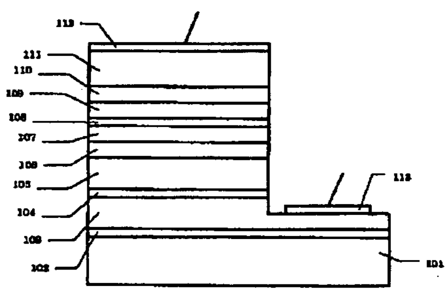
【図10】従来の技術を用いた窒化ガリウム系レーザの概略断面図である。

【図11】従来の技術を用いた窒化ガリウム系発光ダイオードの概略断面図である。

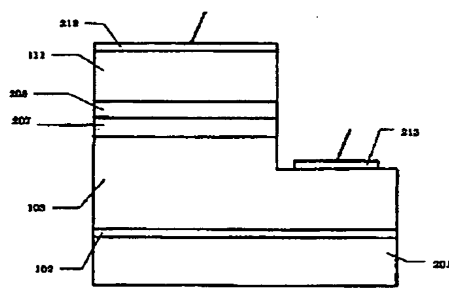
【符号の説明】

101　（11－20）面を表面とするサファイア基板
102　窒化ガリウム低温成長バッファ層
103　N型窒化ガリウムコンタクト層
104　N型$In_{0.05}Ga_{0.95}N$クラック防止層
105　N型$Al_{0.07}Ga_{0.93}N$クラッド層
106　N型窒化ガリウム光ガイド層
107　多重量子井戸活性層
108　ｐ型$Al_{0.1}Ga_{0.9}N$層
109　ｐ型窒化ガリウム光ガイド層
110　ｐ型$Al_{0.07}Ga_{0.93}N$クラッド層
111　ｐ型窒化ガリウムコンタクト層
112　ニッケルおよび金からなるｐ電極
113　チタンおよびアルミニウムからなるN電極
201　（0001）面を表面とするサファイア基板
207　$In_{0.2}Ga_{0.8}N$発光層
208　$Al_{0.1}Ga_{0.9}N$層
212　金からなるｐ電極
213　アルミニウムからなるN電極
308　ｐ型ＡｌＧａＮ層
401　ｐ型$Al_{0.05}Ga_{0.95}N$層
402　ｐ型$Al_{0.075}Ga_{0.925}N$層
403　ｐ型$Al_{0.1}Ga_{0.9}N$層
404　ｐ型$Al_{0.125}Ga_{0.875}N$層
405　ｐ型$Al_{0.15}Ga_{0.85}N$層
501　窒化ガリウム層
502　多重量子井戸構造
503　$Al_{0.1}Ga_{0.9}N$層
608　ｐ型$Al_{0.2}Ga_{0.8}N$層

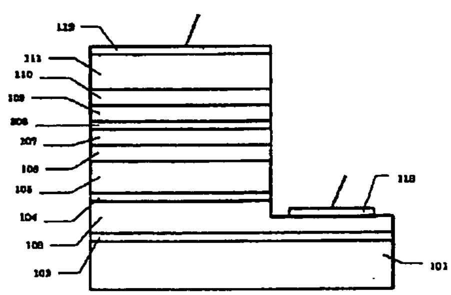
【図1】



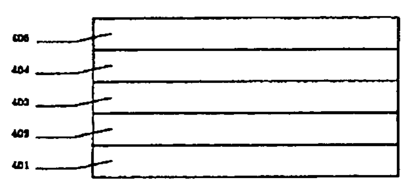
【図2】



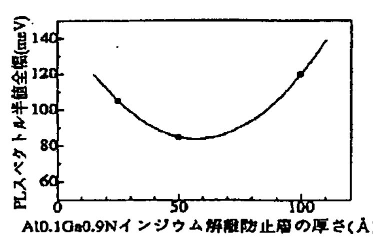
【図3】



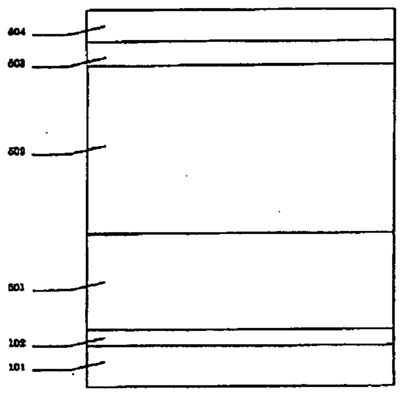
【図4】



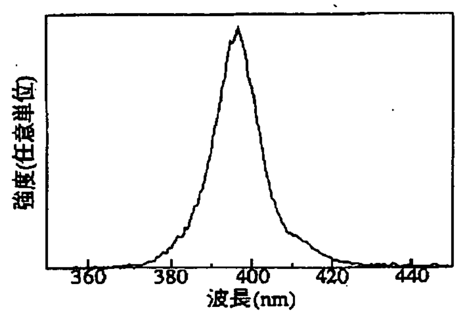
【図9】



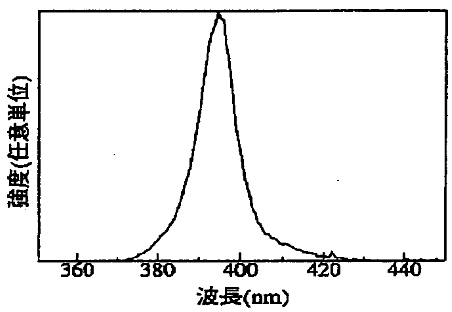
【図５】



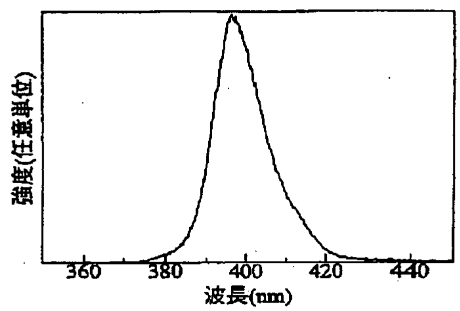
【図６】



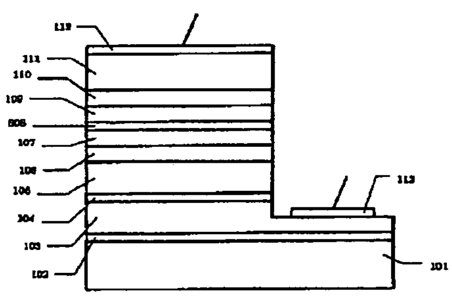

【図７】



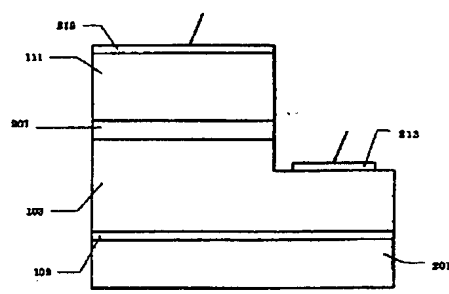

【図８】




【図１０】



【図１１】



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CLAIMS

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[Claim(s)]

[Claim 1] InGaN It is the crystal-growth method of the gallium-nitride system semiconductor layer containing a layer. It is Inx Ga1-xN at substrate 600-degree-C or more temperature of 900 degrees C or less. Inx Ga1-x N of a monostromatic or two or more layers which contains a layer (0< x<=1) further at least The process which forms a layer (0<=x<=1), The process which forms the monostromatic or the two or more layers Alx Ga1-x N layer (0<=x<=1) which contains further an Alx Ga1-x N layer (0< x<=1) at least continuously with the aforementioned process at substrate 600-degree-C or more temperature of 900 degrees C or less, the process which makes substrate temperature 900 degrees C or more -- the aforementioned sequence -- at least -- containing -- and between the number of layers N of the aforementioned Alx Ga1-x N layer (0<=x<=1), the thickness di (i= 1, ..., N) of each class, and the aluminum composition xi (i= 1, ..., N) of each class,

[Equation 1]

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

The crystal-growth method of the gallium-nitride system semiconductor layer characterized by filling an unrelated relation.

[Claim 2] The crystal-growth method of the gallium-nitride system semiconductor layer characterized by being the crystal-growth method of a gallium-nitride system semiconductor layer according to claim 1, and for the aforementioned AlxGa1-x N layer (0<=x<=1) consisting of two or more layers, and aluminum composition of a two or more aforementioned layers Alx Ga1-x N layer (0<=x<=1) applying and increasing from a substrate side to a front-face side.

[Claim 3] Are the manufacture method of the gallium-nitride system light emitting device containing an InGaN layer, and an Inx Ga1-x N layer (0< x<=1) is further included at least at substrate 600-degree-C or more temperature of 900 degrees C or less. The process which forms a monostromatic or a two or more layers Inx Ga1-x N layer (0<=x<=1), The process which forms the monostromatic or the two or more layers Alx Ga1-x N layer (0<=x<=1) which contains further an Alx Ga1-x N layer (0< x<=1) at least continuously with the aforementioned process at substrate 600-degree-C or more temperature of 900 degrees C or less, the process which makes substrate temperature 900 degrees C or more -- the aforementioned sequence -- at least -- containing -- and between the number of layers N of the aforementioned Alx Ga1-x N layer (0<=x<=1), the thickness di (i= 1, ..., N) of each class, and the aluminum composition xi (i= 1, ..., N) of each class,

[Equation 2]

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

The manufacture method of the gallium-nitride system light emitting device characterized by filling an unrelated relation.

[Claim 4] The manufacture method of the gallium-nitride system light emitting device characterized by being the manufacture method of a gallium-nitride system light emitting device according to claim 3, and for the aforementioned Alx Ga1-x N layer (0<=x<=1) consisting of two or more layers, and aluminum composition of a two or more aforementioned layers Alx Ga1-x N layer (0<=x<=1) applying and increasing from a substrate side to a front-face side.

[Claim 5] It is the manufacture method of the gallium-nitride system light emitting device which is the manufacture method of a gallium-nitride system light emitting device according to claim 3 or 4, and is characterized by the aforementioned Inx Ga1-x N layer (0<=x<=1) being a barrier layer or a luminous layer.

[Claim 6] The monostromatic or the two or more layers InxGa1-x N layer (0<=x<=1) which contains further at least the InxGa1-x N layer (0< x<=1) which grew on the substrate and the aforementioned substrate at substrate 600-degree-C or more temperature of 900 degrees C or less, An Alx Ga1-x N layer (0< x<=1) is further included at least following the aforementioned Inx Ga1-x N layer (0<=x<=1) at substrate 600-degree-C or more temperature of 900 degrees C or less. It has the Alx Ga1-x N layer (0< x<=1) which made substrate temperature 900 degrees C or more, and formed it after growing up a monostromatic or a two or more layers Alx Ga1-x N layer (0<=x<=1). Between the number of layers N of the aforementioned Alx Ga1-x N layer (0<=x<=1),

the thickness di (i= 1, ..., N) of each class, and the aluminum composition xi (i= 1, ..., N) of each class,
[Equation 3]

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

The gallium-nitride system light emitting device characterized by filling an unrelated relation.
[Claim 7] The gallium-nitride system light emitting device characterized by being a gallium-nitride system light emitting device according to claim 6, and for the aforementioned Alx Ga1-x N layer (0<=x<=1) consisting of two or more layers, and aluminum composition of a two or more aforementioned layers Alx Ga1-x N layer (0<=x<=1) applying and increasing from a substrate side to a front-face side.
[Claim 8] The gallium-nitride system light emitting device characterized by being a gallium-nitride system light emitting device according to claim 6 or 7, and being the aforementioned Inx Ga1-x N layer (0<=x<=1) barrier layer or a luminous layer.

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DETAILED DESCRIPTION

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[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] this invention contains at least one layer of semiconductor layers expressed with general formula Inx Ga1-x N (0< x<=1) -- it is further -- it is -- it is related with the crystal-growth method of a gallium-nitride system semiconductor layer of having Inx Ga1-x N (0<=x<=1) of two or more layers
[0002] moreover, at least one layer of semiconductor layers expressed with general formula Inx Ga1-x N (0< x<=1) is included -- it is further -- it is -- it is related with the gallium-nitride system light emitting device which has Inx Ga1-x N (0<=x<=1) of two or more layers, and its manufacture method
[0003]
[Description of the Prior Art] Compared with other general compound semiconductors, such as an indium phosphide and a gallium arsenide, forbidden-band energy of a gallium nitride is large. Therefore, the application to the light emitting device over which the semiconductor (following gallium-nitride system semiconductor) expressed with general formula Inx Aly Ga1-x-y N (0<=x<=1, 0<=y<=1, 0 <=x+y<=1) is covered ultraviolet from green, especially semiconductor laser (following only laser) is expected.
[0004] the crystal growth of the former and a gallium nitride -- the substrate

temperature of about 900 degrees C or more -- being also required -- since the crystal growth of a semiconductor layer expressed with ****** and general formula Inx Ga1-x N (0<=x<=1) had the high vapor pressure of an indium, it was performed at the substrate temperature of 600 degrees C or about 900 degrees C which is low temperature comparatively

[0005] <<conventional example 1>> Drawing 10 is the outline cross section of the gallium-nitride system laser in which the barrier layer of multiplex quantum well structure was formed by the crystal-growth method of the conventional InGaN layer (S. Nakamuraet aluminum., Extended Abstracts of 1996 International Conferenceon Solid State Devices and Materials, yokohama, 1996, pp. 67-69). In drawing 10 this gallium-nitride system laser (11-20) On the silicon on sapphire 101 used as a front face, a field Thickness 300A 3 micrometers in thickness by which the gallium-nitride low-temperature growth buffer layer 102 of undoping of (angstrom) and silicon were added 0.1 micrometers in thickness by which the N type gallium-nitride contact layer 103 and silicon were added N type In0.05Ga0.95N crack prevention layer 104, 0.1 micrometers in thickness by which the N type aluminum0.07Ga0.93N clad layer 105 with a thickness of 0.4 micrometers by which silicon was added, and silicon were added In0.2Ga0.8 of undoping of the N type gallium-nitride light-guide layer 106 and thickness 25A (angstrom) The multiplex quantum well structure barrier layer 107 of seven periods which consist of N quantum well layers and In0.05Ga0.95N barrier layers of undoping of thickness 50A (angstrom), and p type aluminum0.2 of thickness 200A (angstrom) by which magnesium was added 0.1 micrometers in thickness by which Ga0.8 N layer 608 and magnesium were added 0.2 micrometers in thickness by which p type gallium-nitride light-guide layer 109, the p type aluminum0.07Ga0.93N clad layer 110 with a thickness of 0.4 micrometers by which magnesium was added, and magnesium were added The N electrode 113 which consists of the p electrode 112, titanium (the 1st layer), and aluminum (the 2nd layer) which consist of p type gallium-nitride contact layer 111, nickel (the 1st layer), and gold (the 2nd layer) of is formed. The multiplex quantum well structure barrier layer 107 and p mold aluminum0.2 Ga0.8 N layer 608 are 800 degrees C in substrate temperature, and p type gallium-nitride light-guide layer 109, the p type aluminum0.07Ga0.93N clad layer 110, and p type gallium-nitride contact layer 111 were formed at the substrate temperature of 1020 degrees C.

[0006] <<conventional example 2>> Drawing 11 is the outline cross section of the conventional gallium-nitride system light emitting diode in which the luminous layer was formed by the crystal-growth method of the conventional InGaN layer (S. Nakamura et aluminum., Jpn.J.Appl.phys.32(1993) L8). In drawing 11 this gallium-

nitride system light emitting diode (0001) On the silicon on sapphire 201 used as a front face, a field 4 micrometers in thickness by which the gallium-nitride low-temperature growth buffer layer 102 of undoping of thickness 250A (angstrom) and silicon were added In0.2 of thickness 200A (angstrom) by which the N type gallium-nitride contact layer 103 and silicon were added The Ga0.8 N luminous layer 207, p type gallium-nitride contact layer 111 by which magnesium was added, the p electrode 212 which consists of gold, and the N electrode 213 which consists of aluminum are formed. aluminum0.2 Ga0.8 N layer 608 of the In0.2 Ga0.8 N luminous layer 207 and undoping is 800 degrees C in substrate temperature, and p type gallium-nitride contact layer 111 was formed at the substrate temperature of 1020 degrees C.

[0007]

[Problem(s) to be Solved by the Invention] In the gallium-nitride system laser which was shown in drawing 10 and in which the barrier layer was formed by the crystal-growth method of the conventional InGaN layer After formation of the multiplex quantum well structure barrier layer 107 with a substrate temperature of 800 degrees C is completed, In order to form p type gallium-nitride light-guide layer 109, in case the temperature up of the substrate is carried out to 1020 degrees C, in order to prevent that the indium in the multiplex quantum well structure barrier layer 107 dissociates Rather than the multiplex quantum well structure barrier layer 107, the multiplex quantum well structure barrier layer 107 is touched, and aluminum0.2 Ga0.8 N layer 608 is formed in the front-face side at the same substrate temperature of 800 degrees C as the multiplex quantum well structure barrier layer 107. A lattice constant Inx Ga1-x N (0<=x<=1) and Alx Ga1-x N (0< x<=1) to also differ However, ******, In the conventional example 1, with 200A (angstrom), since [ thick and ] the thickness of aluminum0.2 Ga0.8 N layer 608 is as large as aluminum composition 0.2 A big lattice strain joins the multiplex quantum well structure barrier layer 107, and crystalline aggravation of the multiplex quantum well structure barrier layer 107 is brought about. On the other hand, it is thin in the thickness of p mold aluminum0.2 Ga0.8 N layer 608, or when aluminum composition is made small, there is a possibility that it may not be prevention, about the indium in the multiplex quantum well structure barrier layer 107 dissociating by the temperature up of a substrate.

[0008] In the gallium-nitride system light emitting diode in which the luminous layer was formed by the crystal-growth method of the conventional InGaN layer shown in drawing 11 After formation of the In0.2Ga0.8 N luminous layer 207 with a substrate temperature of 800 degrees C is completed, In order to form p type gallium-nitride contact layer 111, in case the temperature up of the substrate is carried out to 1020

degrees C, the indium in the In0.2 Ga0.8 N luminous layer 207 dissociates, and there is a possibility that light may not be emitted on the luminescence wavelength as a design value.

[0009] The purpose of this invention contains further an Inx Ga1-x N layer (0< x<=1) at least. The indium in the gallium-nitride system semiconductor layer which has a monostromatic or the Inx Ga1-x N growth phase (0<=x<=1) of two or more layers comparatively formed at low temperature It prevents dissociating substrate temperature in connection with considering as 900 degrees C or more. And crystalline aggravation of an Inx Ga1-x N growth phase (0<=x<=1) can be minimized. A front-face side is touched at an Inx Ga1-x N growth phase (0<=x<=1) rather than an Inx Ga1-x N growth phase (0<=x<=1). By clarifying composition of the monostromatic or the two or more layers Alx Ga1-x N indium dissociation prevention layer (0<=x<=1) comparatively formed at low temperature which contains further an Alx Ga1-x N layer (0< x<=1) at least, and the range of thickness It is offering the crystal-growth method which can form a crystalline good Inx Ga1-xN growth phase (0<=x<=1).

[0010] Furthermore, it is offering a gallium-nitride system light emitting device with sufficient properties, such as threshold current, using such a crystal-growth method.

[0011]

[Means for Solving the Problem] The crystal-growth method of the gallium-nitride system semiconductor of this invention The process which forms the monostromatic or the two or more layers Inx Ga1-x N layer (0<=x<=1) which contains further an Inx Ga1-x N layer (0< x<=1) at least at substrate 600-degree-C or more temperature of 900 degrees C or less, The process which forms the monostromatic or the two or more layers Alx Ga1-x N layer (0<=x<=1) which contains further an Alx Ga1-x N layer (0< x<=1) at least continuously with the aforementioned process at substrate 600-degree-C or more temperature of 900 degrees C or less, The process which makes substrate temperature 900 degrees C or more is included at least in the aforementioned sequence, and it is

[0012] between the number of layers N of the aforementioned Alx Ga1-x N layer (0<=x<=1), the thickness di (i= 1, ..., N) of each class, and the aluminum composition xi (i= 1, ..., N) of each class.

[Equation 4]

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

[0013] It is characterized by filling an unrelated relation.

[0014] Moreover, the aforementioned Alx Ga1-x N layer (0<=x<=1) consists of two or more layers, and it is characterized by aluminum composition of a two or more

aforementioned layers Alx Ga1-x N layer (0<=x<=1) applying and increasing from a substrate side to a front-face side.

[0015] The manufacture method of the gallium-nitride system light emitting device of this invention The process which forms the monostromatic or the two or more layers Inx Ga1-x N layer (0<=x<=1) which contains further an Inx Ga1-x N layer (0< x<=1) at least at substrate 600-degree-C or more temperature of 900 degrees C or less, The process which forms the monostromatic or the two or more layers Alx Ga1-x N layer (0<=x<=1) which contains further an Alx Ga1-x N layer (0< x<=1) at least continuously with the aforementioned process at substrate 600-degree-C or more temperature of 900 degrees C or less, The process which makes substrate temperature 900 degrees C or more is included at least in the aforementioned sequence, and it is [0016] between the number of layers N of the aforementioned Alx Ga1-x N layer (0<=x<=1), thickness di (i= 1, ..., N) of each class, and the aluminum composition xi (i= 1, ..., N) of each class.

[Equation 5]

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

[0017] It is characterized by filling an unrelated relation.

[0018] Moreover, the aforementioned Alx Ga1-x N layer (0<=x<=1) consists of two or more layers, and it is characterized by aluminum composition of a two or more aforementioned layers Alx Ga1-x N layer (0<=x<=1) applying and increasing from a substrate side to a front-face side.

[0019] The gallium-nitride system light emitting device of this invention contains further at least the Inx Ga1-x N layer (0< x<=1) which grew on the substrate and the aforementioned substrate at substrate 600-degree-C or more temperature of 900 degrees C or less. An Alx Ga1-x N layer (0< x<=1) is further included at least following a monostromatic or a two or more layers Inx Ga1-x N layer (0<=x<=1), and the aforementioned Inx Ga1-x N layer (0<=x<=1) at substrate 600-degree-C or more temperature of 900 degrees C or less. It has the Alx Ga1-x N layer (0< x<=1) which made substrate temperature 900 degrees C or more, and formed it after growing up a monostromatic or a two or more layers Alx Ga1-x N layer (0<=x<=1). It is [0020] between the number of layers N of the aforementioned Alx Ga1-x N layer (0<=x<=1), the thickness di (i= 1, ..., N) of each class, and the aluminum composition xi (i= 1, ..., N) of each class.

[Equation 6]

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

[0021] It is characterized by filling an unrelated relation.

[0022] Moreover, the aforementioned Alx Ga1-x N layer (0<=x<=1) consists of two or more layers, and it is characterized by aluminum composition of a two or more aforementioned layers Alx Ga1-x N layer (0<=x<=1) applying and increasing from a substrate side to a front-face side.

[0023]

[Embodiments of the Invention] The gestalt of operation of this invention is explained in detail with reference to a drawing. With the gestalt of this operation, the Inx Ga1-x N layer (0< x<=1) comparatively formed at low temperature on the substrate is included further at least. In order to prevent that the indium in a monostromatic or a two or more layers Inx Ga1-x N layer (0<=x<=1) (it is hereafter described as an Inx Ga1-x N growth phase (0<=x<=1)) dissociates in connection with the temperature up of a substrate A front-face side is touched at an Inx Ga1-x N growth phase (0<=x<=1) rather than an Inx Ga1-x N growth phase (0<=x<=1). The monostromatic or the two or more layers Alx Ga1-x N layer (0<=x<=1) (it is hereafter described as an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1)) which contains further at least the Alx Ga1-x N layer (0< x<=1) comparatively formed at low temperature is formed.

[0024] Usually, although growth of GaN is performed at the substrate temperature of about 1000 degrees C or more, this is temperature to which not only N atom but Ga atom evaporates. However, an elevated temperature (about 1200 degrees C or more) is further needed for evaporation of aluminum atom. Therefore, when a substrate is made into 900 degrees C or more for growth, such as GaN, after growing up an Inx Ga1-x N growth phase (0<=x<=1) and an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1) at substrate 600-degree-C or more temperature of 900 degrees C or less, Ga atom evaporates from an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1). For this reason, an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1) turns into an Alx Ga1-x N layer (0< x<=1) to which aluminum composition became large from the temperature up front, and this layer prevents the omission of In atom. In addition, the rate of evaporation of Ga changes depending on a standby time after carrying out a temperature up in the temperature at the time of forming an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1), the temperature after a temperature up, and the speed of a temperature up until it begins growth etc.

[0025] Since a lattice constant differs from an Inx Ga1-x N growth phase (0<=x<=1), the Alx Ga1-x N layer (0< x<=1) to which aluminum composition created here at the time of a temperature up became large will give aggravation to the crystallinity of an Inx Ga1-x N growth phase (0<=x<=1).

[0026] In order to minimize the influence of aggravation of this crystallinity, its attention was paid to the product of aluminum composition in an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1), and thickness as a parameter of the Alx Ga1-x N layer (0< x<=1) which became large [ aluminum composition ] by evaporation of Ga atom. In order that aluminum composition and thickness of an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1) may investigate the influence which it has on an Inx Ga1-x N growth phase (0<=x<=1) layer, The aluminum composition 0.1 and thickness composition and thickness of an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1) The aluminum0.1 Ga0.9 N layer of 25A (angstrom) (sample 1), Three kinds of samples which the aluminum composition 0.1 and thickness make as the aluminum0.1 Ga0.9 N layer (sample 2) of 50A (angstrom) and the aluminum composition 0.1, and thickness makes the aluminum0.1 Ga0.9 N layer (sample 3) of 100A (angstrom) were created.

[0027] Hereafter, the range with optimal composition of the Alx Ga1-x N indium dissociation prevention layer (0<=x<=1) formed in contact with an Inx Ga1-x N growth phase (0<=x<=1) layer and thickness is explained.

[0028] Drawing 5 is an outline cross section common to three kinds of created samples. Setting to drawing 5 , a sample is 330 micrometers in thickness by the organic metalization study vapor growth. To silicon-on-sapphire top 101 used as a front face, a field (11-20) 1 micrometer in the gallium-nitride low-temperature buffer layer 102 and thickness of undoping The multiplex quantum well structure 502 of five periods which consist of In0.2 Ga0.8 N quantum well layers of thickness 30A (angstrom) of undoping, and gallium-nitride barrier layers of thickness 90A (angstrom) of undoping at **************** 501 and the substrate temperature of 650 degrees C, 0.1 micrometers in thickness of undoping after forming the aluminum0.1Ga0.9N indium dissociation prevention layer 503 of undoping and carrying out a temperature up to the substrate temperature of 1050 degrees C The gallium-nitride layer 504 was formed.

[0029] The thickness of aluminum0.1 Ga0.9 N layer 503 drawing 6 was indicated to be to drawing 5 is as a result of [ of pL spectrum / in / the room temperature of the sample 3 of 100A (angstrom) / thickness / of aluminum0.1 Ga0.9 N layer 503 / the thickness of aluminum0.1 Ga0.9 N layer 503 the sample 1 of 25A (angstrom), and drawing 7 , and / in drawing 8 ] / measurement. / the sample 2 of 50A (angstrom) As the excitation light source in measurement of pL spectrum, it is the wavelength of 325Nm. helium-Cd laser was used.

[0030] Although aluminum0.2 Ga0.8 N layer 608 of the conventional example is thickness 200A (angstrom) and aluminum composition 0.2 Even if it makes the

thickness of an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1), and the product of aluminum composition smaller than aluminum0.2 Ga0.8 N layer 608 of the conventional example Since a lattice strain with more unnecessary making the product of thickness and aluminum composition small is not introduced into an InGaN layer when there is no trouble in the purpose of preventing the maceration of an indium, it is desirable.

[0031] However, in order that only the alumimium nitride (AlN) of under a monoatomic layer may remain when Ga atom evaporates altogether from an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1) at the time of a substrate temperature up if the product of composition and thickness becomes below 2A (angstrom) grade, trouble is in the purpose of preventing the maceration of an indium. Therefore, as for the minimum of the product of aluminum composition of an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1), and thickness which grows, it is desirable that it is larger than 2A (angstrom).

[0032] the full width at half maximum of pL spectrum shown in drawing 6 in samples 1-3 on the other hand -- 105meV(s) the full width at half maximum of pL spectrum shown in drawing 7 -- 85meV(s) the full width at half maximum of pL spectrum shown in drawing 8 -- 120meV(s) it is -- the full width at half maximum of pL spectrum shown in drawing 6 and drawing 5 compared with drawing 7 becomes large

[0033] The graph which shows the relation of the full width at half maximum of the AL0.1 Ga0.9 N indium dissociation prevention layer thickness obtained from the measurement result of pL spectrum of samples 1-3 and pL spectrum is shown in drawing 9 . For the full width at half maximum of pL spectrum in the threshold current density and the room temperature of a barrier layer of gallium-nitride system laser, the full width at half maximum of pL spectrum [ in / the room temperature of the barrier layer / in order for there to be a close relation and to realize 2 or less-about 2 kA/cm for threshold current density ] is 120meV(s). It is desirable that it is below a grade. When aluminum composition of an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1) and the product of thickness become large, an unnecessary distortion will join an Inx Ga1-x N growth phase (0<=x<=1), and will affect the full width at half maximum of pL spectrum. Therefore, as for the upper limit of the thickness of an Alx Ga1-x N indium dissociation prevention layer (0<=x<=1), and the product of aluminum composition, it is desirable that it is smaller than 10A (angstrom).

[0034] Thus, the relation of the number of layers N of the Alx Ga1-x N layer (0<=x<=1) used as an indium dissociation prevention layer, the thickness di (i= 1, ..., N) of each class, and the aluminum composition xi (i= 1, ..., N) of each class is the following (1)

formula.

[0035]

[Equation 7]

$$2[\text{Å}] \leq \sum_{i=1}^{n} x_i d_i \leq 10[\text{Å}]$$

[0036] Things are understood that what is necessary is just a ******** range.

[0037] In addition, in drawing 9 , it is brought about from two trade-ofves called unnecessary distorted reduction with antiflashing of an indium that pL spectrum full width at half maximum (meV ) becomes the smallest near 60A (angstrom) as thickness in aluminum composition 0.1.

[0038] The example which applied the gestalt of operation of this invention to below is explained.

[0039] <<example 1>> Drawing 1 is the outline cross section of the gallium-nitride system laser of this invention formed with the application of the composition of an indium dissociation prevention layer and the relation of thickness which were explained with the gestalt of operation. In drawing 1 this gallium-nitride system laser (11-20) On the silicon on sapphire 101 used as a front face, a field Thickness 300A 3 micrometers in thickness by which the gallium-nitride low-temperature growth buffer layer 102 of undoping of (angstrom) and silicon were added 0.1 micrometers in thickness by which the N type gallium-nitride contact layer 103 and silicon were added N type In0.05Ga0.95N crack prevention layer 104, 0.4 micrometers in thickness by which silicon was added 0.1 micrometers in thickness by which the N type aluminum0.07Ga0.93N clad layer 105 and silicon were added The N type gallium-nitride light-guide layer 106 is formed. At the substrate temperature of 800 degrees C, thickness 25A In0.2 of undoping of (angstrom) The multiplex quantum well structure barrier layer 107 of seven periods which consist of Ga0.8 N quantum well layers and In0.05Ga0.95N barrier layers of undoping of thickness 50A (angstrom), and p type aluminum0.1 of thickness 50A (angstrom) by which magnesium was added Ga0.9 N layer 108 is formed. 0.1 micrometers in thickness by which magnesium was added after that at the substrate temperature of 1020 degrees C 0.4 micrometers in thickness by which p type gallium-nitride light-guide layer 109 and magnesium were added 0.2 micrometers in thickness by which the p type aluminum0.07Ga0.93N clad layer 110 and magnesium were added p type gallium-nitride contact layer 111 of is formed. Titanium (the 1st layer) and aluminum (the 2nd layer) are used for the N electrode 113 at the p electrode 112 using nickel (the 1st layer) and gold (the 2nd layer).

[0040] In an example 1, by adopting 50A (angstrom) as thickness of aluminum0.1 Ga0.9

N layer 108, and adopting 0.1 as aluminum composition It reconciled preventing the maceration of the indium in the multiplex quantum well structure barrier layer 107 by aluminum0.1 Ga0.9 N layer 108, and minimizing crystalline aggravation of the multiplex quantum well structure barrier layer 107 by aluminum0.1 Ga0.9 N layer 108. Therefore, low oscillation threshold current is realized compared with the gallium-nitride system laser in which the barrier layer was formed by the crystal-growth method of the conventional InGaN layer shown in the conventional example 1.

[0041] <<example 2>> Drawing 2 is the outline cross section of the gallium-nitride system light emitting diode of this invention with which the luminous layer was formed using the crystal-growth method of the InGaN layer of this invention. In drawing 2 this gallium-nitride system light emitting diode (0001) 4 micrometers in thickness by which the gallium-nitride low-temperature growth buffer layer 102 of undoping of thickness 250A (angstrom) on the silicon on sapphire 201 which uses a field as a front face, and silicon were added The N type gallium-nitride contact layer 103 is formed. aluminum0.2 Ga0.8 N layer 208 of undoping of the In0.2 Ga0.8 N luminous layer 207 of thickness 200A (angstrom) by which silicon was added at the substrate temperature of 800 degrees C, and thickness 25A (angstrom) is formed. p type gallium-nitride contact layer 111 by which magnesium was added at the substrate temperature of 1020 degrees C is formed. Aluminum is used for gold and the N electrode 213 at the p electrode 212.

[0042] In an example 2, by adopting 25A (angstrom) as thickness of aluminum0.2 Ga0.8 N layer 208, and adopting 0.2 as aluminum composition The maceration of the indium in the In0.2 Ga0.8 N luminous layer 207 is prevented by aluminum0.2 Ga0.8 N layer 208, Since it reconciled minimizing crystalline aggravation of the In0.2 Ga0.8N luminous layer 207 by aluminum0.2 Ga0.8 N layer 208, Compared with the gallium-nitride system light emitting diode in which the luminous layer was formed by the crystal-growth method of the conventional InGaN layer shown in the conventional example 2, the luminescence wavelength as a design value and the emission spectrum of narrow full width at half maximum are realized.

[0043] <<example 3>> Drawing 3 is the outline cross section of the gallium-nitride system laser of this invention with which the barrier layer was formed using the crystal-growth method of the InGaN layer of this invention. In drawing 3 this gallium-nitride system laser (11-20) On the silicon on sapphire 101 used as a front face, a field Thickness 300A 3 micrometers in thickness by which the gallium-nitride low-temperature growth buffer layer 102 of undoping of (angstrom) and silicon were added 0.1 micrometers in thickness by which the N type gallium-nitride contact layer 103 and silicon were added N type In0.05Ga0.95N crack prevention layer 104, 0.4 micrometers

in thickness by which silicon was added 0.1 micrometers in thickness by which the N type aluminum0.07Ga0.93N clad layer 105 and silicon were added The N type gallium-nitride light-guide layer 106 is formed. at the substrate temperature of 800 degrees C The multiplex quantum well structure barrier layer 107 of seven periods which consist of In0.2 Ga0.8 N quantum well layers of undoping of thickness 25A (angstrom) and In0.05Ga0.95N barrier layers of undoping of thickness 50A (angstrom) is formed. After that, 0.1 micrometers in thickness by which the p type AlGaN layer 308 of thickness 50A (angstrom) by which magnesium was added at the substrate temperature of 1020 degrees C, and magnesium were added 0.4 micrometers in thickness by which p type gallium-nitride light-guide layer 109 and magnesium were added 0.2 micrometers in thickness by which the p type aluminum0.07Ga0.93N clad layer 110 of and magnesium were added p type gallium-nitride contact layer 111 is formed. Titanium (the 1st layer) and aluminum (the 2nd layer) are used for the N electrode 113 in nickel (the 1st layer) and gold (the 2nd layer) at the p electrode 112.

[0044] The p type AlGaN layer 308 consists of two or more layers of aluminum composition different, respectively. The outline cross section showing the detail of the p type AlGaN layer 308 is shown in drawing 4 . In drawing 4 The p type AlGaN layer 308 Thickness 10A by which magnesium was added p type aluminum0.1 of thickness 10A (angstrom) by which p mold aluminum0.05Ga0.95N layer 401 of (angstrom), p mold aluminum0.075 Ga0.925 N layer 402 of thickness 10A (angstrom) by which magnesium was added, and magnesium were added It consists of Ga0.9 N layer 403, p mold aluminum0.125 Ga0.875 N layer 404 of thickness 10A (angstrom) by which magnesium was added, and p mold aluminum0.15Ga0.85N layer 405 of thickness 10A (angstrom) by which magnesium was added.

[0045] In the example 3, it reconciled preventing the maceration of the indium in the multiplex quantum well structure barrier layer 107 by the aforementioned AlGaN layer 308, and minimizing crystalline aggravation of the multiplex quantum well structure barrier layer 107 by the aforementioned AlGaN layer 308 by [ which aluminum composition applies the AlGaN layer 308 to a front-face side from a substrate side, and increase ] constituting by five layers of thickness 10A (angstrom), respectively. Therefore, even if compared with the gallium-nitride system laser in which the barrier layer was formed by the crystal-growth method of the InGaN layer of this invention shown in the example 1, low oscillation threshold current is realized further.

[0046] Although gallium-nitride system light emitting diode given in gallium-nitride system laser and an example 2 given in the above-mentioned example 1 and an example 3 is formed on the silicon on sapphire which uses a field (11-20) as a front face, even if it

forms a field (0001) on the silicon on sapphire used as a front face, it is convenient to operation of this invention.

[0047] Furthermore, a gallium-nitride system light emitting device given in the above-mentioned examples 1-3 is a silicon-carbide substrate or MgAl 2O4, even if it does not form a field (0001) or (11-20) a field on the silicon on sapphire used as a front face. When fields other than a substrate, a gallium-nitride substrate or (0001) a field, and (11-20) a field are formed on other substrates called the silicon on sapphire used as a front face, it is convenient to operation of this invention.

[0048] Moreover, operation of this invention is not restricted to the gallium-nitride system light emitting device of the structure shown in the above-mentioned example, and it is convenient in the gallium-nitride system light emitting device of various combination, such as thickness of each class, composition of each class, doping concentration of each class, and an electrode material.

[0049] Moreover, the Alx Ga1-x N layer (0<=x<=1) which prevents the maceration of an indium does not need to be p type with which magnesium as shown in the above-mentioned example 1 and the example 3 was added, or undoping as shown in the above-mentioned example 2, and even if it is the N type by which silicon etc. was added, trouble does not have it in operation of this invention.

[0050] Moreover, the Alx Ga1-x N layer (0<=x<=1) which prevents the maceration of an indium Even if it consists of two or more layers from which aluminum composition differs and it does not increase [ aluminum composition as it indicated to be to the above-mentioned example 3 even if applies and ] from a substrate side to a front-face side There is an effect equivalent to the Alx Ga1-x N layer (0<=x<=1) of the monolayer of the gallium-nitride system laser shown in the example 1. Moreover, it is applicable also to an example 2.

[0051] moreover, aluminum0.1 Ga0.9 Non GaN on aluminum0.2Ga0.8 N on the indium dissociation layer of a multilayer like GaN -- each aluminum composition and thickness -- taking into consideration -- and 600 degrees C or more 900 degrees C or less -- what is necessary is just to grow up the multilayer at low temperature comparatively

[0052] In addition, although this example indicated the case where an Inx Ga1-x N growth phase (0<=x<=1) was made into a barrier layer or a luminous layer, it is not restricted to this.

[0053]

[Effect of the Invention] In the gallium-nitride system semiconductor layer which has the monostromatic or the Inx Ga1-x N growth phase (0<=x<=1) of two or more layers in which this invention contains further an Inx Ga1-x N layer (0< x<=1) at least Even if

substrate temperature becomes 900 degrees C or more, the maceration of an indium can be prevented and crystalline aggravation of an Inx Ga1-x N growth phase (0<=x<=1) can be minimized.

[0054] Moreover, since a crystalline good Inx Ga1-x N growth phase (0<=x<=1) can be formed, although a light emitting device with sufficient properties, such as threshold current, is offered, it can do.

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DESCRIPTION OF DRAWINGS

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[Brief Description of the Drawings]

[Drawing 1] It is the outline cross section of the gallium-nitride system laser of this invention with which the barrier layer was formed using the crystal-growth method of the InGaN layer of this invention shown in the example 1.

[Drawing 2] It is the outline cross section of the gallium-nitride system light emitting diode of this invention which was shown in the example 2 and with which the luminous layer was formed using the crystal-growth method of the InGaN layer of this invention.

[Drawing 3] It is the outline cross section of the gallium-nitride system laser of this invention with which the barrier layer was formed using the crystal-growth method of the InGaN layer of this invention shown in the example 3.

[Drawing 4] It is the outline cross section of the AlGaN indium dissociation prevention layer of the gallium-nitride system laser of this invention shown in drawing 7 .

[Drawing 5] It is the outline cross section of samples 1-3.

[Drawing 6] It is the graph which shows the measurement result of pL spectrum of a sample 1.

[Drawing 7] It is the graph which shows the measurement result of pL spectrum of a sample 2.

[Drawing 8] It is the graph which shows the measurement result of pL spectrum of a sample 3.

[Drawing 9] It is the graph in samples 1-3 which shows the relation of the full width at half maximum of aluminum0.1 Ga0.9 N indium dissociation prevention layer thickness and pL spectrum.

[Drawing 10] It is the outline cross section of the gallium-nitride system laser using the Prior art.

[Drawing 11] It is the outline cross section of gallium-nitride system light emitting diode using the Prior art.

[Description of Notations]

101 (11-20) Silicon on Sapphire Which Uses Field as Front Face
102 Gallium-Nitride Low-temperature Growth Buffer Layer
103 N Type Gallium-Nitride Contact Layer
104 N Type In0.05Ga0.95N Crack Prevention Layer
105 N Type Aluminum0.07Ga0.93N Clad Layer
106 N Type Gallium-Nitride Light-Guide Layer
107 Multiplex Quantum Well Barrier Layer
108 P Mold Aluminum0.1 Ga0.9 N Layer
109 P Type Gallium-Nitride Light-Guide Layer
110 P Type Aluminum0.07Ga0.93N Clad Layer
111 P Type Gallium-Nitride Contact Layer
112 P Electrode Which Consists of Nickel and Gold
113 N Electrode Which Consists of Titanium and Aluminum
201 (0001) Silicon on Sapphire Which Uses Field as Front Face
207 In0.2 Ga0.8 N Luminous Layer
208 Aluminum0.1 Ga0.9 N Layer
212 P Electrode Which Consists of Gold
213 N Electrode Which Consists of Aluminum
308 P Type AlGaN Layer
401 P Mold Aluminum0.05Ga0.95N Layer
402 P Mold Aluminum0.075 Ga0.925 N Layer
403 P Mold Aluminum0.1 Ga0.9 N Layer
404 P Mold Aluminum0.125 Ga0.875 N Layer
405 P Mold Aluminum0.15Ga0.85N Layer
501 Gallium-Nitride Layer
502 Multiplex Quantum Well Structure
503 Aluminum0.1 Ga0.9 N Layer
608 P Mold Aluminum0.2 Ga0.8 N Layer